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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

FREE-SPINNING-TUNNEL INVESTIGATION OF EFFECT OF INVERTED-VEE VENTRAL FINS ON SPIN AND RECOVERY CHARACTERISTICS OF CHANCE VOUGHT XF8U-1 AIRPLANE

TED NO. NACA DE 392

By Walter J. Klinar and Stanley H. Scher

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SUMMARY

An investigation has been made in the Langley 20-foot free-spinning tunnel to determine the effect on erect spin and recovery characteristics of adding a pair of large ventral fins in the form of an inverted vee.

The model results indicated that the addition of the inverted vee-type ventral fins had a favorable effect in that the fast-rotating flat spin which had been obtained with the model before the ventrals were added was eliminated. Recovery characteristics of the corresponding airplane with ventral fins installed, however, are not considered satisfactory unless the maximum aileron deflections of the design are increased to about ±25°.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, brief tests were performed in the Langley 20-foot free-spinning tunnel to determine the effect on erect spin and recovery characteristics of adding a pair of large ventral fins in the form of an inverted vee on the bottom of the fuselage of a 1/25-scale model of the Chance Vought XF8U-1 airplane. These ventral fins are retracted to a horizontal position when

[redacted]

the airplane lands and are extended to provide additional directional stability after the airplane takes off. Previous tests were made on this model without the ventral fins installed and the results are presented in reference 1. In the present investigation, tests were made of the model in the clean condition for the basic loading condition (take-off loading, 300-nautical-mile fighter equipped with guns, center of gravity at 33 percent of the mean aerodynamic chord) used in the tests reported in reference 1.

SYMBOLS

b wing span, ft

S wing area, sq ft

$\bar{c}$ mean aerodynamic chord, ft

$x/\bar{c}$ ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord

$z/\bar{c}$ ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)

m mass of airplane, slugs

I_X,I_Y,I_Z moments of inertia about X, Y, and Z body axes, respectively, slug-ft^2

$\frac{I_X - I_Y}{mb^2}$ inertia yawing-moment parameter

$\frac{I_Y - I_Z}{mb^2}$ inertia rolling-moment parameter

$\frac{I_Z - I_X}{mb^2}$ inertia pitching-moment parameter

ρ air density, slug/cu ft

μ relative density of airplane, $\frac{m}{\rho Sb}$

α angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg

[redacted]

ϕ	angle between span axis and horizontal, deg
V	full-scale true rate of descent, ft/sec
Ω	full-scale angular velocity about spin axis, rps

MODEL AND TEST CONDITIONS

The 1/25-scale model of the Chance Vought XF8U-1 airplane used in the investigation reported in reference 1 was also used in the present investigation. A three-view drawing of the model with the inverted-vee ventral fins installed is shown in figure 1, and a sketch showing the ventral fins in more detail is shown in figure 2. The dimensions of the ventral fins were specified by the Chance Vought Aircraft Company. The dimensional characteristics of the airplane are listed in table I.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 30,000 feet (ρ = 0.000889 slug/cu ft). A remote control mechanism was used in the model to actuate the controls for the recovery attempts, sufficient hinge moments being exerted on the controls to reverse them fully and rapidly.

The normal maximum control deflections of the model are:

Rudder, deg	6 right, 6 left
Horizontal tail, deg	30 trailing edge up
Ailerons, deg	15 up, 15 down

Some intermediate settings of the controls were used in the tests and these are listed specifically along with the test results.

Mass characteristics and inertia parameters for the loading tested on the model are presented in table II. The testing technique, the precision of the test results, and the limits of accuracy of the mass characteristics of the model for the present tests were essentially the same as those reported in reference 1.

RESULTS AND DISCUSSION

The results of the present investigation are presented in table III. Recovery attempts were made only by moving the ailerons inasmuch as reference 1 had shown that the ailerons were the primary controls affecting recovery. In order to facilitate comparison with the previous test results obtained on the model without the ventral fins added, a chart from reference 1 is repeated as chart 1 of this paper. As may be seen from this chart and as was explained in reference 1, the model without ventral fins exhibited two types of spins: a flat spin with an angle of attack of about 80° and a rotational rate corresponding to almost 0.5 revolution per second on the airplane, and a somewhat steeper oscillatory spin with an angle of attack of approximately 65° and a rotational rate about half that of the flatter spin. As was also indicated in reference 1, the optimum control manipulation for recovery on the airplane is simultaneous full rudder reversal to against the spin and aileron movement to full with the spin with the stick held back. Even if this optimum technique is employed, it was indicated that the spin-recovery characteristics of the airplane could be poor.

As may be seen by comparing the results on table III and chart 1, installing the inverted-vee ventral fins on the model had a favorable effect in that the fast-rotating flat spin previously obtained on the model was eliminated and only a slower rotating oscillatory spin resulted. The recovery characteristics of the corresponding airplane would still be considered unsatisfactory, however, because of the poor recoveries that were obtained on the model when the ailerons were moved to two-thirds (±10°) of their full deflection with the spin (stick right in a right erect spin) from an initial condition with ailerons 1/3 against the spin and the horizontal tail 2/3 up (stick 2/3 back). (See spin 1 in table III.) As is pointed out in reference 1, recoveries from this control configuration by utilizing two-thirds of the full aileron deflection with the spin as a recovery measure are taken as a criterion in determining whether the recovery characteristics of the corresponding airplane would be expected to be satisfactory. Recoveries in excess of about $2\frac{1}{4}$ turns are considered to be unsatisfactory. Although only slow unsatisfactory recoveries (presented in table III for the above control setting and control manipulation) were obtained from the steeper oscillatory spin, because of this oscillatory nature of the spin, some faster recoveries might also be possible and may have been obtained if many more recovery attempts had been made. It should also be pointed out that these tests were conducted with about the most rearward center of gravity attainable on the Chance Vought XF8U-1 airplane (33 percent $\bar{c}$) and that, for center-of-gravity positions forward of this point, the recovery characteristics of the model may be somewhat better. (See ref. 1.)

When the ailerons were moved to full with the spin (±15°) from the preceding control setting (ailerons 1/3 against the spin and stick 2/3 back; spin 2 in table III), better recovery characteristics were obtained, but they were still considered to be marginal. It appears that it would be necessary to increase the maximum aileron deflections on the airplane to about ±25° for the airplane recovery characteristics to be satisfactory because of the spin-tunnel criterion of requiring satisfactory results with only two-thirds deflection of the controls. Optimum control recovery technique with the increased aileron deflections should be simultaneous full reversal of rudder and movement of ailerons to full with the spin with the stick maintained full back; when recovery becomes imminent, the stick should be moved forward.

Some brief tests were also made with the ailerons set 1/3 against the spin and the horizontal tail set to 2/3 up with the size of the ventral fins about doubled as shown in figure 3. For these tests, the model would not spin and consistently damped its applied launching rotation and dived within about 5 turns after launching. (These results are not presented in tabular form.)

CONCLUSIONS

Based on the results of tests of a 1/25-scale model of the Chance Vought XF8U-1 airplane in the Langley 20-foot free-spinning tunnel, the following conclusions are drawn regarding the effect on erect spin and recovery characteristics of the addition of a pair of large ventral fins in the form of an inverted vee:

1. Adding the inverted-vee ventral fins had a favorable effect in that the fast-rotating flat spins obtained without the ventral fins were eliminated. The recovery characteristics of the design with the ventrals installed are still not considered satisfactory.

2. If maximum aileron deflections on the airplane could be increased from $\pm 15^{\circ}$ to about $\pm 25^{\circ}$, the spin-recovery characteristics of the airplane would be considered satisfactory, based on present standards used in interpreting spin-tunnel test results. Optimum use of controls would be simultaneous full reversal of rudder and movement of ailerons to full with the spin with the stick maintained full back; when recovery becomes imminent, the stick should be moved forward.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., December 11, 1956.

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REFERENCE

1. Klinar, Walter J., Lee, Henry A., and Wilkes, L. Faye: Free-Spinning-Tunnel Investigation of a 1/25-Scale Model of the Chance Vought XF8U-1 Airplane - TED No. NACA DE 392. NACA RM SL56L31b, Bur. Aero., 1957.

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE CHANCE VOUGHT XF8U-1 AIRPLANE

AS REPRESENTED BY THE MODEL TESTED

Overall length, ft	53.06
Wing:	
Span, ft	35.67
Area (including fixed chord-extension), sq ft	385.33
Root chord, in.	202.00
Tip chord (not including chord-extension), in.	49.93
Tip chord (including chord extension), in.	55.93
Mean aerodynamic chord, in.	141.40
Leading edge of $\bar{c}$ rearward of leading edge of root chord, in.	92.68
Aspect ratio (area includes chord-extendion)	3.30
Taper ratio (not including chord-extendion)	0.25
Taper ratio (including chord-extension)	0.28
Dihedral, deg	-5
Sweepback at quarter chord, deg	42
Incidence, deg	-1
Airfoil section:	
Root	NACA 65A006
Tip	NACA 65A005
Ailerons:	
Total area, sq ft	41.98
Span, percent of b/2	40.38
Horizontal tail:	
Span, ft	18.17
Area, sq ft	93.45
Sweepback at quarter chord, deg	45
Root chord, in.	108.05
Tip chord, in.	15.96
Aspect ratio	3.53
Dihedral, deg	5.42
Airfoil section:	
Root	Modified NACA 65A006
Tip	Modified NACA 65A004
Vertical tail:	
Height, ft	12.08
Total area (including dorsal), sq ft	82.36
Rudder area (back of hinge line), sq ft	12.39
Sweepback at quarter chord, deg	45
Root chord at fuselage center line, in.	157.50
Tip chord, in.	41.00
Aspect ratio	1.77
Airfoil section:	
Root	Modified NACA 65A006
Tip	Modified NACA 65A004

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS

FOR THE LOADING TESTED ON THE MODEL

[Moments of inertia are about the center of gravity; all values are for full-scale airplane]

Weight, lb	23,771
$x/\bar{c}$	0.33
$z/\bar{c}$	0.041
μ at sea level	22.58
μ at 30,000 ft	60.39
I_X	11,709
I_Y	82,654
I_Z	89,237
$\frac{I_X - I_Y}{mb^2}$	-756×10^{-4}
$\frac{I_Y - I_Z}{mb^2}$	-70×10^{-4}
$\frac{I_Z - I_X}{mb^2}$	826×10^{-4}

TABLE III.- RESULTS OF FREE-SPINNING-TUNNEL INVESTIGATION TO DETERMINE EFFECTS OF INVERTED-VEE

FINS ON SPIN AND RECOVERY CHARACTERISTICS OF A 1/25-SCALE CHANCE VOUGHT XF8U-1 AIRPLANE M

[Model results presented in terms of full-scale airplane values; loading conditions listed in table II]

Spin	Spin conditions							Recovery at		
	Control settings			α, deg	ϕ, deg	V, ft/sec	Ω, rps	Controls moved to		
	Rudder	Horizontal tail	Ailerons					Rudder	Horizontal tail	Ai
a,b1	6° with	20° trailing edge up	5° against	58 to 74	26U to 19D	292	0.19	Not moved	Not moved	10
a,b2	6° with	20° trailing edge up	5° against	58 to 74	26U to 19D	292	0.19	Not moved	Not moved	15
a3	6° with	20° trailing edge up	15° against	65 to 90	39U to 34D	300	0.21	Not moved	Not moved	15
a,b4	6° with	10° trailing edge up	5° against	62 to 84	39U to 36D	298	0.22	Not moved	Not moved	15
a5	6° with	0°	15° against	50 to 82	32U to 28D	292	0.21	Not moved	Not moved	15

[a]Oscillatory spin; average or range of values presented.

[b]Model sometimes oscillates out of spin without control movement.

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITHOUT VENTRAL FINS

(This chart repeated from reference 1)

[Recovery attempted by control-manipulation technique indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins)]

Airplane XF8U-1	Attitude Erect	Direction Right	Loading: See table II		
Leading-edge flaps undeflected			Center-of-gravity position 33 percent $\bar{c}$	Altitude 30,000 ft	max. rudder defl. ±6° max. aileron defl. ±15°

Model values converted to full scale U - Inner wing up D - Inner wing down

Spin Data

Ailerons $\frac{1}{3}$ against

b		b	
81	9U 12D	50 64	13U 10D
266	0.48	296	0.20

(a)

b			
80	10U 17D		
282	0.38	303	0.23

(a; Ailerons $\frac{1}{3}$ against)

b		b		d
80 87	7U 9D	60 70	9U 2D	NO SPIN
275	0.44	310	0.24	

(c; Horizontal tail full up (Stick back))

e
NO SPIN

Horizontal tail $\frac{2}{3}$ up

b		b	
85	3U 5D	72 82	10U 18D
268	0.43	303	0.23

(a)

Horizontal tail $\frac{1}{3}$ up

b		b	
75 84	5U 13D	56 76	10U 18D
262	0.41	310	0.25

(a)

Ailerons full against (Stick left)

b		b	
79 88	3U 18D	57 68	10U 15D
262	0.56	303	0.20

(a)

Rudder-full-with spin (a):

b		b	
77 86	9U 14D	63 76	10U 13D
276	0.47	303	0.24

Ailerons full with (Stick right)

d
NO SPIN

Horizontal tail full down (Stick forward)

b		b	
78 88	14U 17D	53 70	19U 22D
262	0.56	289	0.23

(a)

b		b	
76 82	10U 10D	54 67	5U 12D
262	0.44	282	0.19

(a)

d
NO SPIN

[a]Two conditions possible.
[b]Oscillatory spin, range or average values given.
[c]Three conditions possible.
[d]Model steepened; then oscillated out of spin.
[e]Model entered a spin in opposite direction.

α (deg)	φ (deg)
V (fps)	Ω (rps)

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL WITHOUT VENTRAL FINS - (Concluded)
(This chart repeated from reference 1)

[Recovery attempted by control-manipulation technique indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins)]

Airplane XF8U-1	Attitude Erect	Direction Right	Loading: See table II		
Leading-edge flaps undeflected			Center-of-gravity position 33 percent $\bar{c}$	Altitude 30,000 ft	max. rudder defl. ±6° max. aileron defl. ±15°

Model values converted to full scale

U - Inner wing up

D - Inner wing down

Recovery data

	Flatter-type spin	Steeper-type spin
R.A	5, 7, 10	
A		[f] 2½
A H.T.	2¾, 3, 5	[g] ½, [f,g] ½
A_1	[g] 2½, [g] 4, [g] 5	

Ailerons ⅓ against

	Flatter-type spin	Steeper-type spin
R.A	7, 10½	[f,h] 1¼, [f,h] 2, [f,h] 2½
A		
A H.T.	4	[f] ½, 1½
R.A. H_o		[f,h] 1, [f,h] 2, [f,h] 4¾, [f,h] ∞

Horizontal tail ⅔ up

	Flatter-type spin	Steeper-type spin
A H.T.	1½, 5	[i] 1, [g] 2¼

	Flatter-type spin	Steeper-type spin
R.A	5, >5	
A		3¾
A H.T.	2, 2	[g] 2, 2¾
A_1	¾, 2½, 3	

Horizontal tail full up (Stick back)

Horizontal tail ⅓ up

	Flatter-type spin	Steeper-type spin
A H.T.	2¼, 2½	½, ¾

	Flatter-type spin	Steeper-type spin
R.A	[i] 6, >12	[i] 1½, [i] 2
A H.T.	4, 4	½, 1

Ailerons full against (Stick left)

	Flatter-type spin	Steeper-type spin
R.A	5, 7, >9	
A		
A H.T.	2½, 3	1, 1¼
A_1	1, 3¼, 4½	[g] 1, [f,g] 1½

Ailerons full with (Stick right)

Horizontal tail full down (Stick forward)

	Flatter-type spin	Steeper-type spin
R.A	5, [j] 8, ⌢	
A H.T.	3, [f] 4	[f] 2, 2¼

	Flatter-type spin	Steeper-type spin
R.A	6, 7	3, >1
A H.T.	[g] 2½, [g] 3	[g] ½, [k] ½

[f]Visual.
[g]After recovery model turned in opposite direction.
[h]Rudder reversed to only ⅔ against the spin and ailerons moved to only ⅔ with the spin.
[i]After recovery model started spinning in opposite direction.
[j]Model recovered in a dive, then went into an aileron roll.
[k]Model recovered in an inverted dive.

Recovery attempted by:	
R	Rudder reversal to full against spin
A	Ailerons moved to full with spin
H.T.	Horizontal tail differentially deflected from laterally neutral to full with spin
A_1	Outboard ailerons taped to normal ailerons and reversed to 45° with spin
H_o	Horizontal tail neutralized

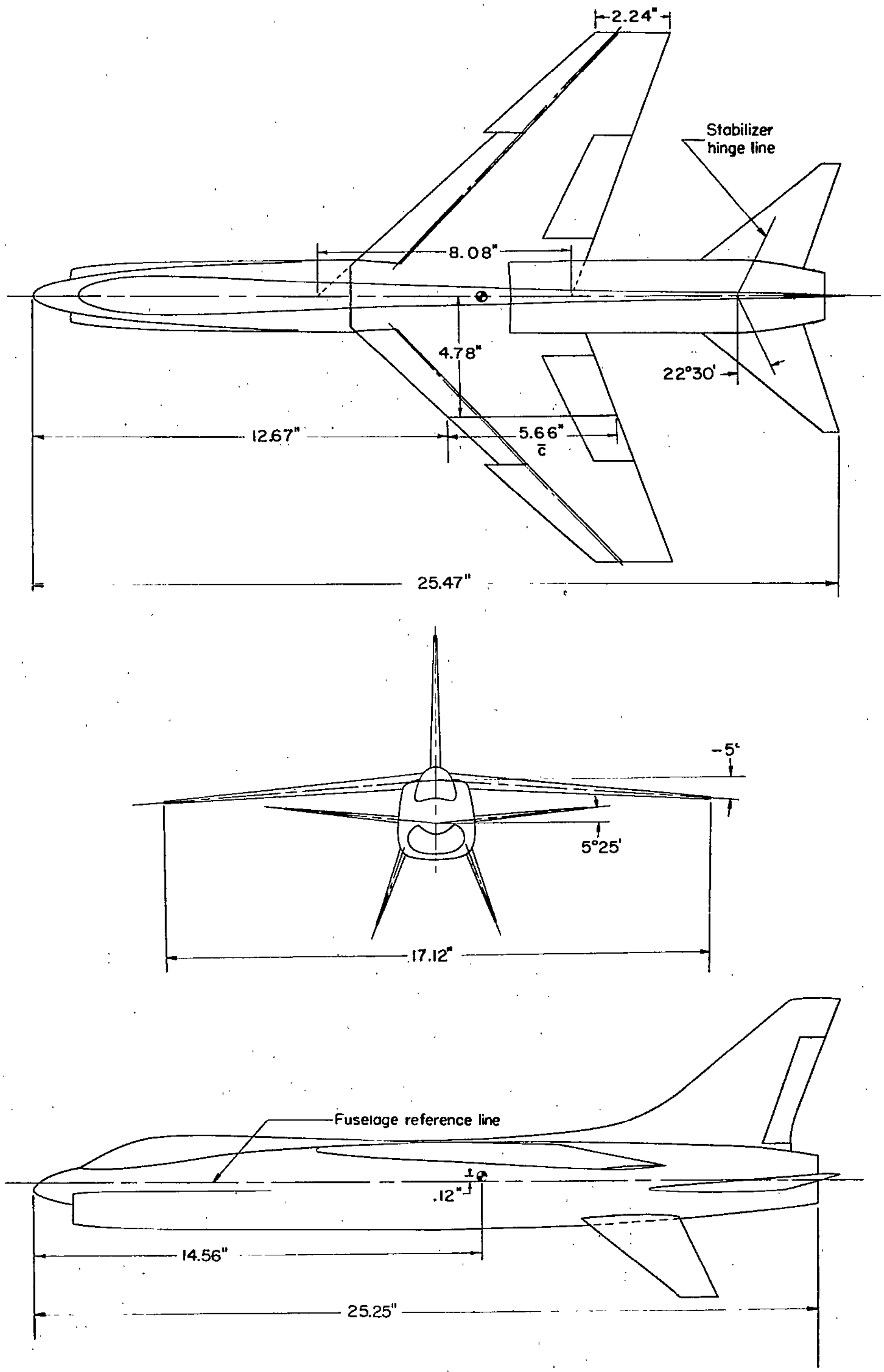

Figure 1.- Three-view drawing of the model with the ventral fins installed.

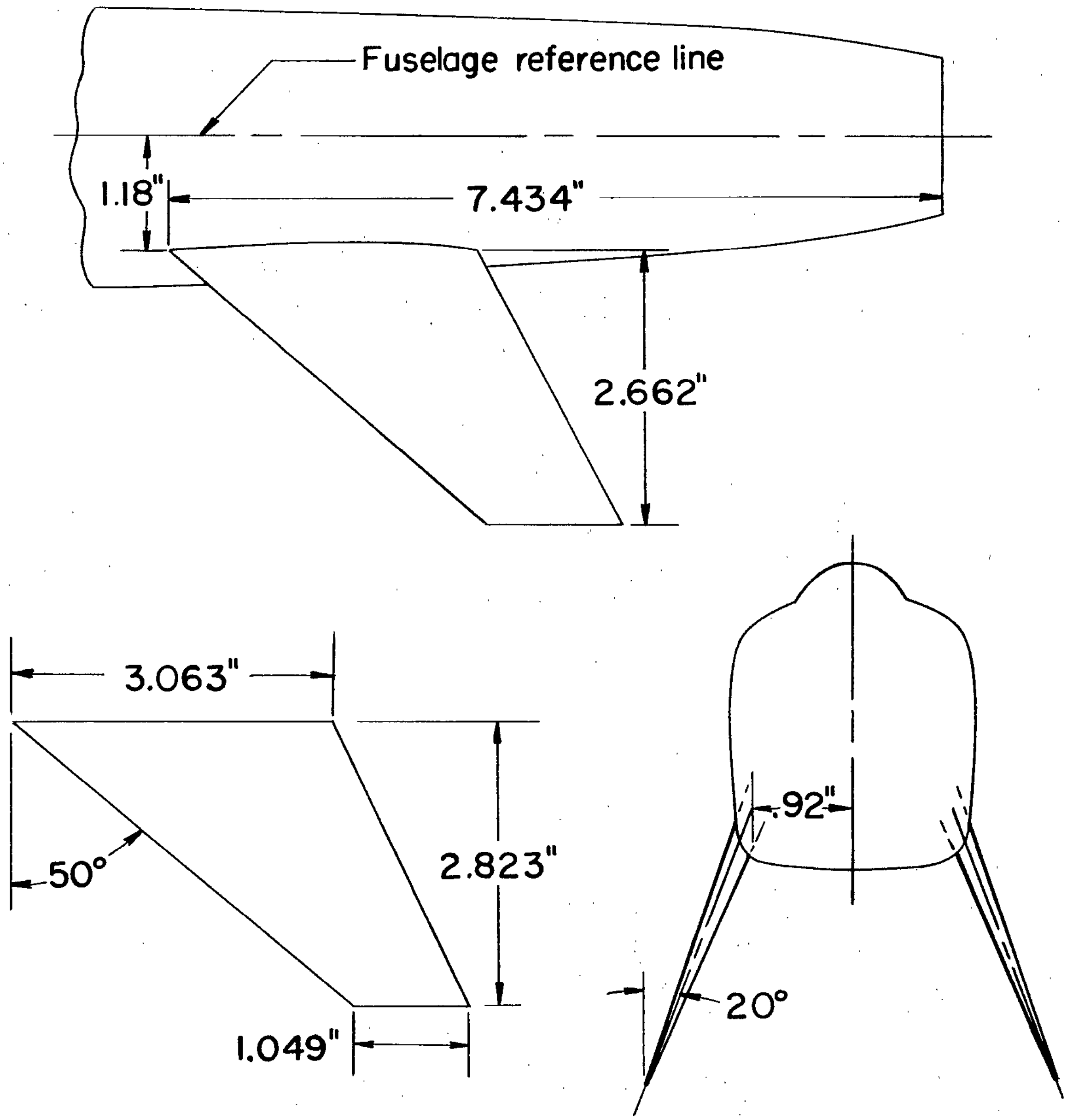

Figure 2.- Sketch showing dimensions and locations of normal ventral fins on model.

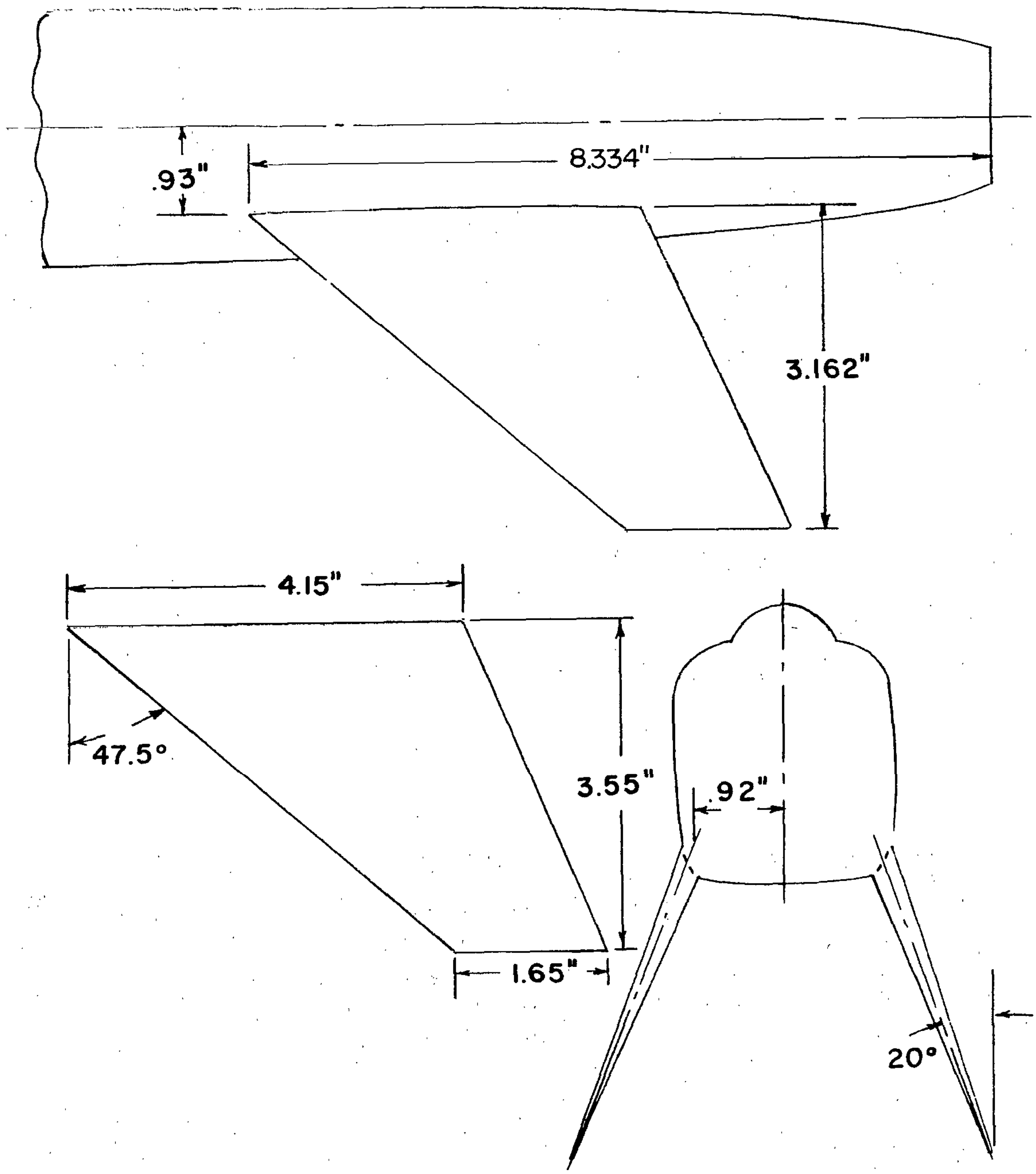

Figure 3.- Sketch showing dimensions and locations of enlarged ventral fins on model.

FREE-SPINNING-TUNNEL INVESTIGATION OF EFFECT OF INVERTED-VEE VENTRAL FINS ON SPIN AND RECOVERY CHARACTERISTICS OF CHANCE VOUGHT XF8U-1 AIRPLANE

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ABSTRACT

An investigation has been made in the Langley 20-foot free-spinning tunnel on a 1/25-scale model of the Chance Vought XF8U-1 airplane to determine the effect of adding inverted-vee ventral fins on the spin and recovery characteristics. These characteristics were affected favorably, but recoveries were not considered to be entirely satisfactory.

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